Roughness Lingual Tactile Sensitivity

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Abstract

There is limited research on lingual tactile sensitivity and it is poorly understood how it relates to food perception. We developed a method to study tongue sensitivity to roughness. Participants were asked to lick sandpapers varying in particle sizes and determine which of two samples was rougher, as well as rate the roughness using a verbally – anchored line scale. Sensitivity measures were linked to demographics (age, sex, race) and anatomical (lingual taste papillae density) factors. The results show that there may be a possible effect of age on suprathreshold sensitivity--the older participants are the less sensitive they become--but the sample size needs to be bigger for the data to be statistically significant. Men may also require a smaller particle size in order to detect a just-noticeable-difference in their roughness threshold. With the currently small sample size there seems to be no influence from taste papillae density, ethnicity, smoker status, age, or gender on threshold and suprathreshold data. Potentially the results could be correlated with other lingual sensitivity tasks (e.g. letter recognition) and further used by the food industry to determine how consumers perceive and like food textures.

Key words: Suprathreshold, just-noticeable-difference threshold, roughness, demographics, line scale

Introduction

There has been a great variety of research on tactile acuity, but not as much specifically on lingual tactile acuity. There are different types of tactile stimuli including edge/form recognition used in letter recognition, or various degrees of roughness, which may contribute to texture perception. However, it is unclear what physiological and/or demographic factors contribute to lingual sensitivity. There is reason to suggest that a higher taste papillae count results in increased sensitivity to be able to determine different lingual textures (Bakke and Vickers 2008). In addition to their involvement in taste, fungiform papillae are surrounded by mechanosensory nerves that correspond with the ability to detect different stimuli, such as differences in texture. (Bakke and Vickers 2008). Thus, the underlying hypothesis is that the more taste papillae a person has on their tongue, the greater sensitivity they will have and better able to distinguish which sandpaper is rougher (Johnson an Yoshioka, 2001).

More research needs to be done in order to be able to fully understand lingual tactile sensitivity and how demographics (age, sex, ethnicity) plays a role in the accuracy of texture detection. It is possible that the older people are the less sensitive they may become due to loss of taste papillae (Petrosino and others 1982). The purpose of this study is to describe how taste papillae numbers and demographics affect lingual tactile sensitivity of roughness. Threshold and suprathreshold information assist in understanding tactile sensitivity of roughness. This information can be used to gain a better understanding of the factors contributing to lingual tactile sensitivity and provide insight into how food texture preferences may develop, which is important to the food industry and restaurant business (Lucasewycz and Mennella 2012). Thus roughness is then related to texture perception (Johnson and Yoshioka 2001).

The theoretical framework for this study is based on lingual tactile acuity as assessed by a modified version of the Essick method (1999) which used a staircase method to determine the threshold of a person's lingual tactile ability to recognize letters (Lucasewycz and Mennella 2012). The current study has been modified and while it still uses a staircase method instead uses a paired comparison of roughness using different grit sizes of sandpaper to obtain a just-noticeable-difference threshold (Meilgarrd and others 2007). The suprathreshold measures can be used to evaluate the perceived intensity across a large range of rough stimuli, whereas the threshold measurement looks at a person's ability to differentiate just-noticeable differences between confusable stimuli having similar roughness (Meilgarrd and others 2007).

Hypothesis

Prior research has shown that there is evidence of large variation in the number of taste papillae, but a higher papillae density suggests better tactile sensitivity. (Bakke and Vickers 2008). Increasing the sample population and adding more people over 40 can give us more insight into lingual tactile sensitivity of roughness. It was thought that older people (+40) would be less sensitive and have lower just-noticeable-difference threshold than younger people. It is also believed that smoker status, ethnicity and gender may play some role in affecting participants responses. Smoker status tends to decrease all sensitivity, and there is no pre-defined effect of the gender and ethnicity demographics that are genetically linked; however, there tends to be an effect in studies from these elements (Lucasewycz and Mennella 2012). This may help industry to provide consumers with products that can satisfy their lingual tactile preferences.

Purpose and Research Objectives

The purpose of this study is to describe how taste papillae count affects threshold and suprathreshold lingual tactile sensitivity of roughness. Demographic information will also be collected on each person participating in the study to further understand how these variables may impact tactile sensitivity of roughness. The research objectives are:

1. Describe the relationship between certain demographic variables (sex, age, ethnicity) of people participating in the study to and tactile sensitivity of roughness.
2. Describe the relationship between taste papillae count and lingual tactile sensitivity of roughness.
3. Determine whether threshold and suprathreshold roughness sensitivity is correlated.

Methods and Materials

Participants were given informed consent, then given a demographic survey to complete. The demographic asked for gender (male or female), age in ten-year brackets (18 – 29, 30 – 39, 40 – 49, 50 – 59, 60 – 69, 70 – 74, 75 or older, prefer not to answer), ethnicity (White Caucasian, Black African American, American Indian or Alaska Native, Hispanic or Latino, Asian Pacidfic Islander, other, prefer not to answer), and smoker status (Are you a smoker? Yes or no). Tongue depressors were affixed with a sandpaper square (how large was the square) to one end containing one of the following particle sizes: 265 um, 82 um, 46.2 um, 21.8 um, 18.3 um, 15.3 um, 12.7 um, 10.3 um, or 8.4 um. The lower particle size was smoother and the higher particle size was rougher. First, suprathreshold sensitivity was assessed using a Generalized Labeled Magnitude Scale (glms) that is verbally – anchored, and participants were given an explanation of how to use the scale. The subject was then asked to use the tip of their tongue to determine where particle sizes 265 um, 82 um, 46.2 um, 21.8 um, 12.7 um, 10.3 um, or 8.4 um lie on the scale. This was used to obtain a psychophysical curve of perceived roughness. For each individual the area under this curve was obtained as a singular measure of roughness sensitivity.

Based on the Essick method (1999), a staircase method was used to determine the threshold of a person's lingual tactile acuity with modifications (Lucasewycz and Mennella 2012). Doing a paired comparison of stimuli, while it was being timed assessed threshold sensitivity. The 21.8 um, 18.3 um, 15.3 um, 12.7 um, or 10.3 um particle sizes were compared to the 8.4 um particle size (reference). The subject was handed two sticks, one containing the reference sandpaper (8.4 um) and the other containing the experimental sandpaper (21.8 um, 18.3 um, 15.3 um, 12.7 um, or 10.3 um), chosen at random. The subject was then asked to lick the sandpaper using the tip of the tongue gently, and asked which stimuli was rougher. If the response was correct then in the next round a finer sandpaper (smaller particle size) was given to the subject, but if the response was incorrect then a rougher sandpaper was given to the subject to compare to 8.4 um. This process was repeated until 8 reversals were obtained and the timer was stopped. A reversal is a change in the subject's performance on the following response (correct response followed by an incorrect response or an incorrect response followed by a correct response). The grit size at each of the eight reversals was averaged in order to determine the smallest particle size difference that could be reliably discriminated.

Finally, each subject had a paper hole reinforcer placed on the tip of the tongue just off the midline of the dyed blue area and a photograph was taken in order to count the number of taste papillae in the circumscribed area and determine the taste papillae density.

Results and Discussion

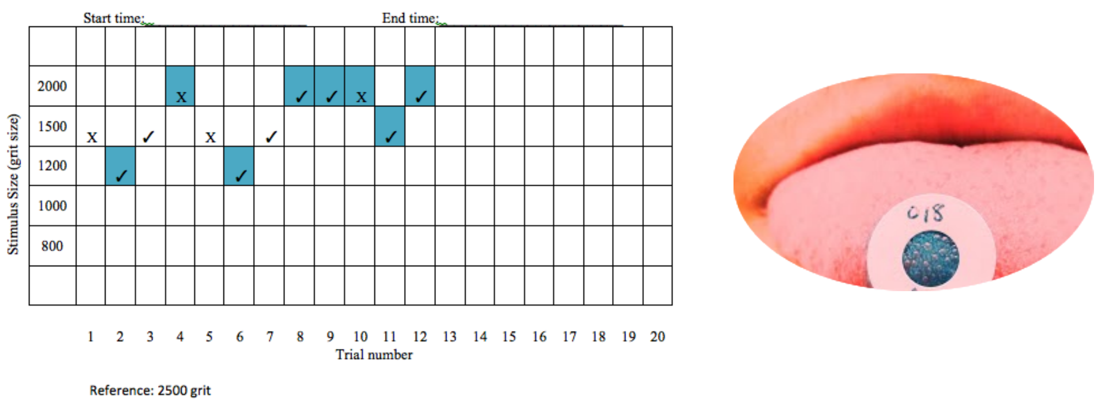

Figure 1. Example a threshold test (left) and taste papillae sample of a small portion of the tongue that is stained with blue dye (right).

In figure 1 an example of the reversals obtained during the just-noticeable-difference threshold test can be seen. This person's just-noticeable-difference threshold probably lies between 12. 7 – 10.3 um particle size (converted from grit size on the scoresheet). Also an example of the how the tongue was dyed can be seen in the above figure as well. Notice that the taste papillae did not become dyed blue. These pink dots were counted in order to determine taste papillae density for participants.

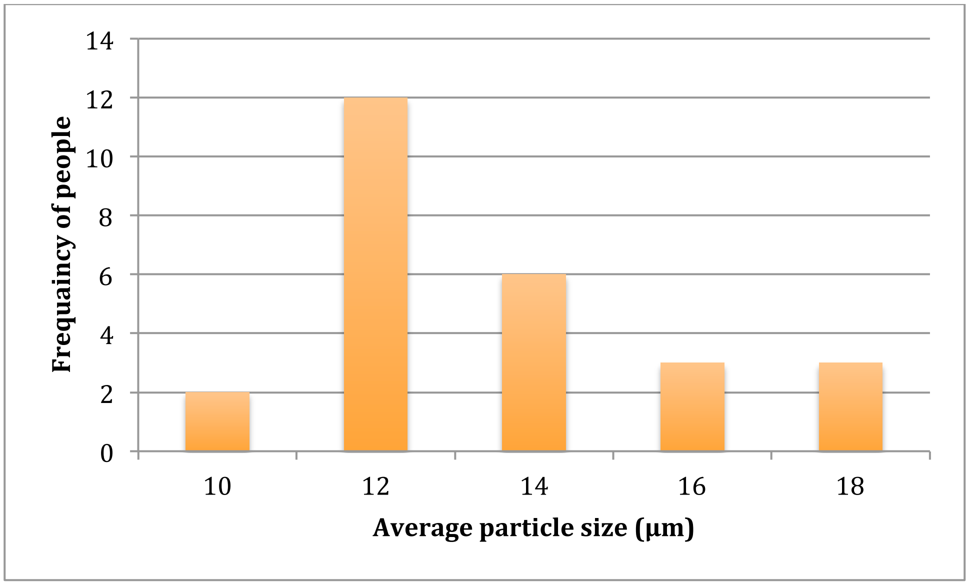

Figure 2. Average threshold expressed as the frequency versus the average particle size (µm) needed to elicit a just-noticeable difference in roughness.

In figure 2, variability exists in the threshold sensitivity to rough stimuli. Most people could discriminate a small difference in particle size; however, some did require larger particle sizes to detect differences in roughness. However, the majority of people tended to need smaller particle sizes to determine a just-noticeable-difference and were thus more sensitive. There is a need to explore why variability exists. There were no significant differences for smoking status ($p = 0.498$), ethnicity ($p = 0.885$), or taste papillae count ($p = 0.443$). Possibly a gender effect contributes to some of this variability. Men needed an average particle size of 11.46 µm to identify a just-noticeable difference in roughness whereas women needed an average particle size of 13.09 µm, $p=0.07$). Men could detect smaller particle differences compared to women, although the effect was not statistically significant, because of small sample size (not enough power).

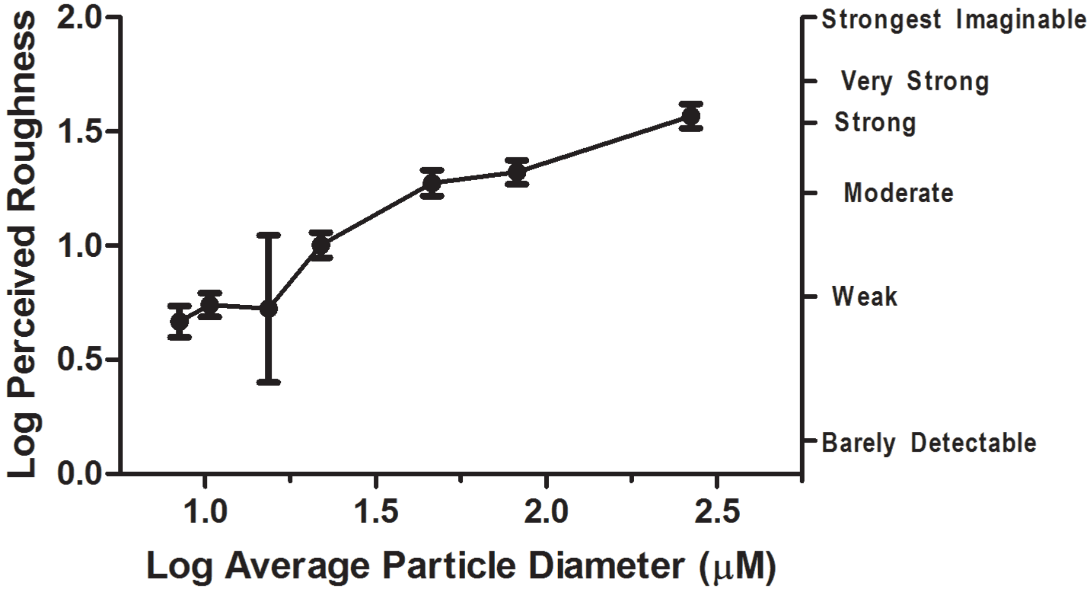

Figure 3. The log of roughness intensity versus the log of the average particle diameter (µm).

In figure 3 there was a plateau at lower perceived roughness, then it transitions to an increase in roughness perception, then it started to plateau at greater roughness values. It is difficult to completely plateau at the higher roughness perception because participants may always think that there is something rougher. The plateaus indicate that stimuli are below and above the perceived roughness threshold. There is a large error bar at about 1.2 µm, which may be the result of the transition between threshold and suprathreshold roughness. This is the point at which a subject can definitely detect roughness, which varies from person to person.

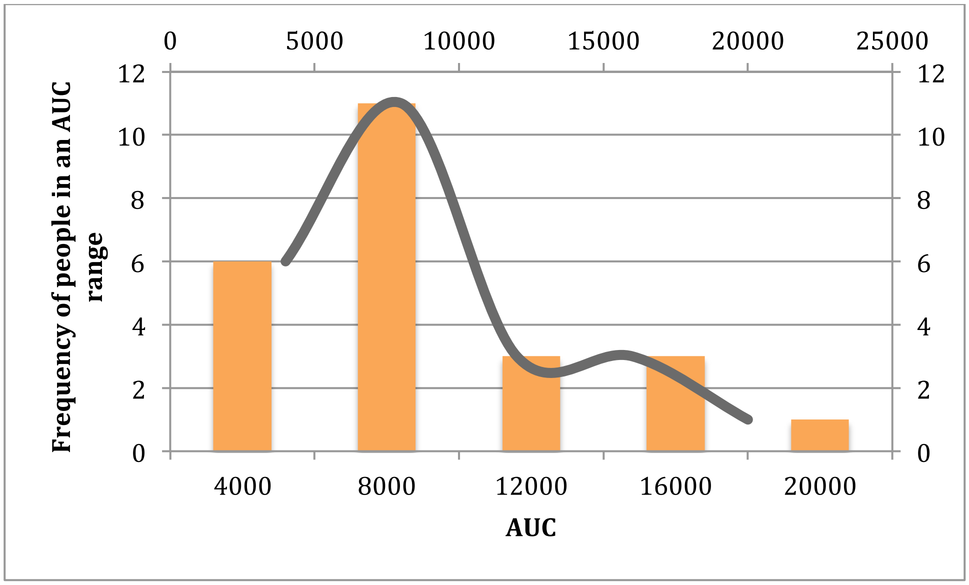

Figure 4. The frequency of people versus the AUC (area under the curve), for suprathreshold psychophysical curve.

Figure 4 shows the area under the curve (AUC) based on the suprathreshold test. It is a singular measurement of sensitivity across the stimulus range. Low AUC's signify shallow slopes on the psychophysical curve, which corresponds to people thinking the stimuli are not extremely rough. There are people with large AUC's that indicate, for a given stimulus range, those people perceived it as rougher than less sensitive people. In figure 4 there was a great variability in roughness sensitivity for the suprathreshold test. Smoking status ($p = 0.974$), ethnicity ($p = 0.500$) and papillae density ($p = 0.970$) had no significant effect on the AUC. However, one contributing factor to this variability could be age. Although age did not significantly contribute to differences in the AUC, this was likely due to a small sample of people over 40 years of age. For that small group, the average AUC was larger compared to the younger panelists. However, with more people we may see an effect of age begin to take place.

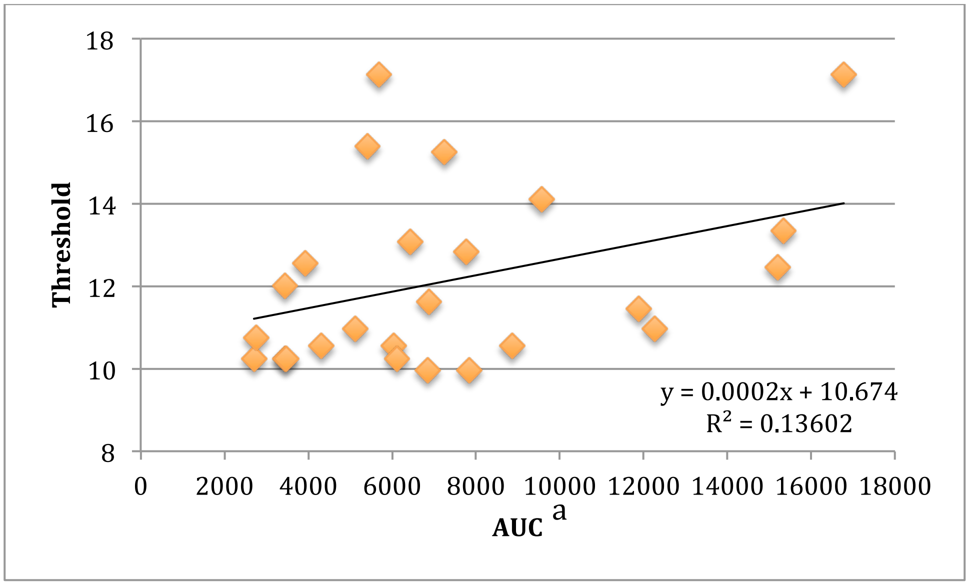

Figure 5. Correlation of threshold versus suprathreshold (AUC) sensitivity.
[a]Area under the curve.

Figure 5 shows that there was no correlation between the tests: threshold does not predict suparthreshold sensitivity. The threshold is measuring a person's ability to differentiate two confusable rough stimuli. Suprathreshold measurement is assessing perceived roughness over a large range of stimuli. These are different tasks and thus do not necessarily need to be linked.

Conclusion

There is great variation in threshold and supratheshold roughness sensitivity. Currently, our sample size is too small to identify significant associations between age and papillae density. However, in the Essick study, papillae density had an effect on letter recognition (Essick and others 2010). There may be an effect of gender on the threshold sensitivity and of age on suprathreshold sensitivity, but more data would have to be collected to determine if this is the case. The Lucasewycz study did not encounter and age effect on letter recognition, but this study only compared moms and kids, so they likely did not go high enough in age to notice an effect (Lucasewycz and Mennella 2012). There seems to be no significant difference due to smoker status, or ethnicity.

By understanding the lingual tactile sensitivity of different people, and what factors play a role into a consumer's perception of roughness or texture, the food and beverage industry can apply this information to improve their products. They can also begin to understand the mechanisms contributing to texture perception and link these to texture preferences. Future studies could possibly include surveys to assesse preferred foods and correlating it with the subject's threshold and/or suprathreshold results. Results could help determine how sensitivity is connected with food texture preferences. This information could then be used to provide consumers with a more enjoyable experience and help improve the food and beverage offerings of the food industry and restaurant business.

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